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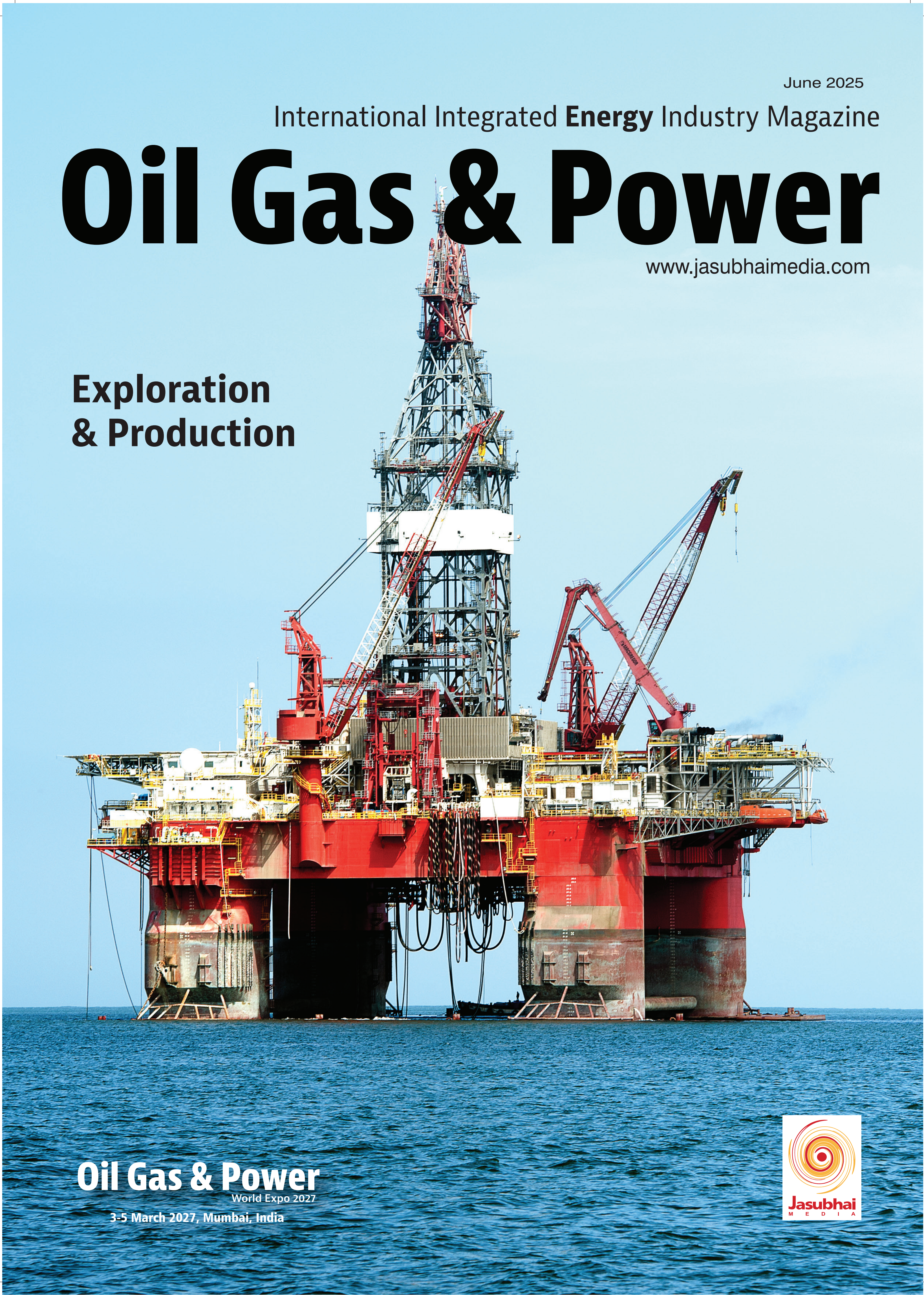

Exploration & Production

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Role of Innovative R&D in Steam Turbine Manufacturing

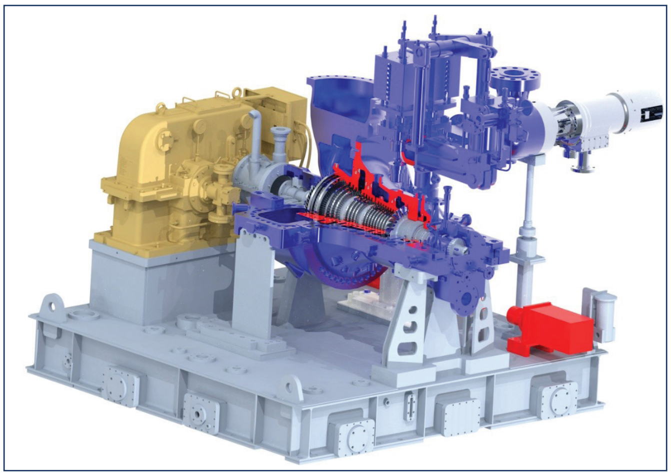
The steam-turbine industry is undergoing a transformative shift, driven by rapid technological advancements and the global transition toward cleaner energy. At the core of this evolution is forward-looking Research and Development (R&D), which is redefining turbine design, efficiency, manufacturing processes and lifecycle support. This article explores how cutting-edge R&D is shaping the future of steam-turbine production — highlighting the role of digital tools, automation, smart factories, workforce upskilling and sustainable practices in building a more resilient and efficient energy landscape.

Efficiency remains the foremost benchmark for steam turbine performance. Today's Research and Development (R&D) efforts focus on innovative thermodynamic cycles, optimized blade profiles and advanced sealing solutions to minimize leakage.

Enhancing Efficiency through Advanced Design

By leveraging Computational Fluid Dynamics (CFD) and Finite Element Analysis (FEA), engineers can digitally simulate flow dynamics, thermal behaviour and structural stress significantly accelerating the design and optimization process.

Exciting concepts such as 3D-contoured blades, advanced sealing and variable-nozzle geometries are already pushing turbines to higher output, lower heat rate and longer life.



PLM Automation & CAD Integration for Manufacturing Accessibility

Modern turbine R&D integrates Product Lifecycle Management (PLM) systems with advanced Computer-Aided Design (CAD) tools, creating a continuous digital thread from concept to production. Automation within PLM enables real-time data sharing across engineering, procurement and manufacturing teams accelerating decision-making, enhancing collaboration and reducing rework.

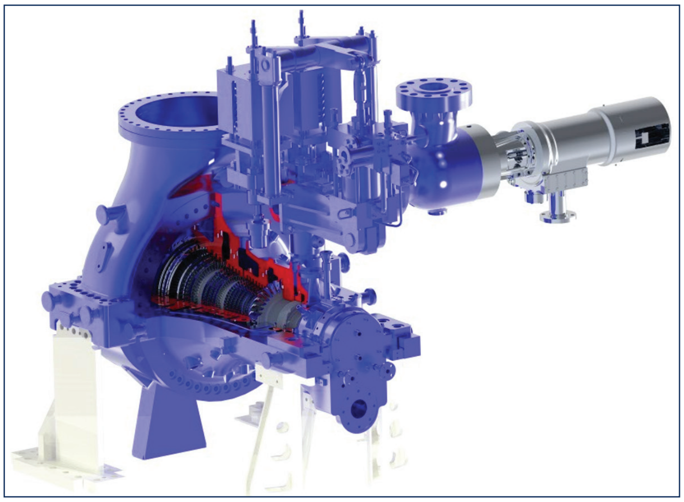
A standout element of this setup is the exploded assembly view that engineers embed directly in the CAD model. Spreading the turbines parts outward in the drawing reveals fit, orientation and clearance in one clear snapshot, letting assembly crews:

- Grasp how each piece relates to the others
- Follow the same step-by-step routine every time
- Spot the tools they need and where they work
- Catch small misalignments before they matter.

Those exploded views then flow into manuals, training videos and real-time shop-floor screens, keeping everyone on the same page whether they are building, servicing, or taking the unit apart.

Robotics in Blading & Turbine Assembly

Robotic automation is reshaping turbine manufacturing by boosting accuracy, speed and consistency, especially during blading and assembly steps.



Key innovations include:

Robotic Blade Installation: Guarantees exact positioning and the same torque across parts, cutting mistakes and saving time.

Robotic Blade Hardening: Delivers steady, even heating along each blade, to improve fatigue strength and overall life.

Collaborative Robots (Cobots): Work beside staff, lifting heavy pieces and perfecting alignments without safety worries.

Automated Guided Vehicles (AGVs): Move materials between stations on schedule, keeping the line running smoothly.

Robotic Welding & Inspection: Make clean, repeatable seams and check quality in real time with built-in sensors.

Together, these advances raise assembly standards, boost reliability and slash rework, meeting today's steam turbine goals.

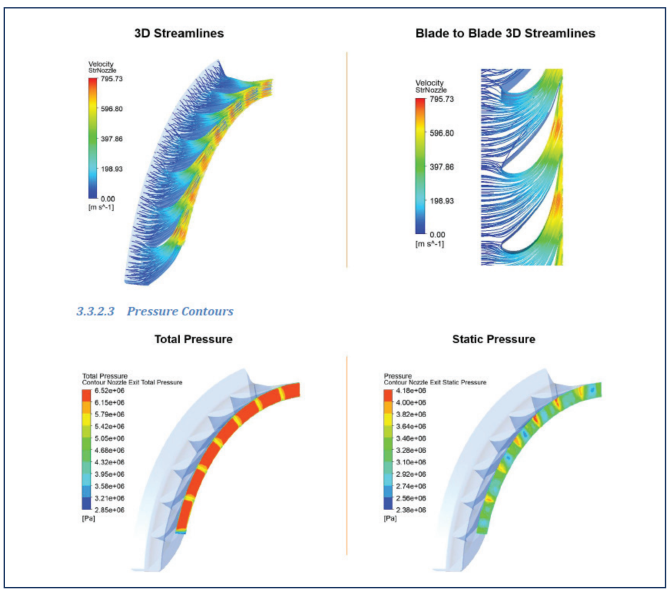
Materials Development for Durability & Performance

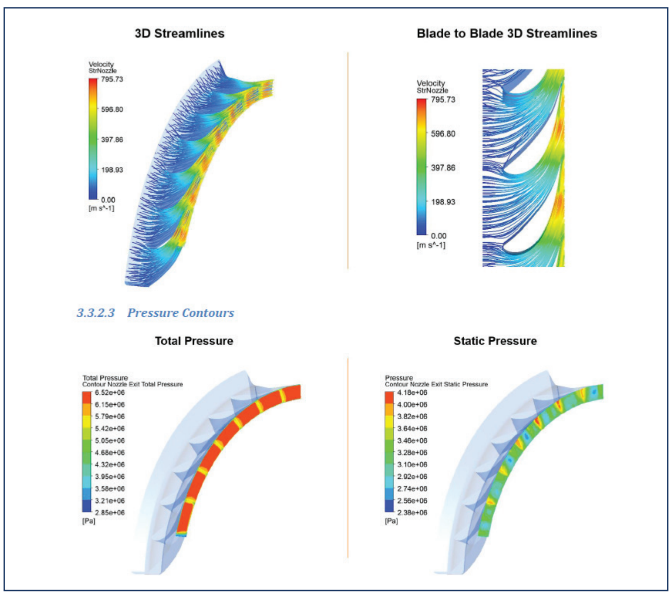
Steam turbines operating in extreme conditions demand materials with exceptional strength, fatigue resistance and thermal stability. To meet these challenges, advanced R&D labs are qualifying nickel-based superalloys, ceramic-matrix composites and thermal-barrier coatings. These innovations enable higher operating speeds while maintaining critical component temperatures within safe limits. Meanwhile, additive manufacturing (or 3D printing) is quickly becoming the preferred method for complex parts, allowing engineers to build lighter, stronger structures with less scrap.

Digitalization & Smart Monitoring

Parallel to materials work, R&D teams are digitizing turbine fleets with smart sensors, cloud analytics and predictive-maintenance platforms. Digital twins - vital, living replicas of each unit simulate loads, troubleshoot faults and adapt control rules without taking hardware offline.

In the field, compact data loggers now pair with AI to scan operating patterns, flag early wear and suggest corrective actions before failures occur. This automated, 24-7 surveillance boosts uptime and stretches the service life of high-value components.





Sustainability & Environmental Compliance

Environmental regulations are increasingly shaping turbine innovation. R&D efforts now prioritize emission reduction, enhanced thermal efficiency and integration into low-carbon hybrid systems. Modern turbine installations increasingly incorporate technologies such as Carbon Capture and Storage (CCS), Waste Heat Recovery (WHR) and Combined Heat and Power (CHP) to support sustainable energy objectives. Material circularity, energy-efficient manufacturing processes and longer maintenance intervals further improve the environmental performance of turbine systems. As part of a larger decarbonization effort, research and development is also driving innovations in sustainable sourcing and resource use. This includes:

- Sourcing raw materials from scrap to reduce mining and extraction impacts
- Maximizing efficiency during part manufacturing
- Tracking the lifecycle of components from production through service and disposal
- Implementing end-of-life recovery and recycling programs to reclaim valuable materials and cut down on landfill waste

These practices contribute to a circular economy framework, lowering the overall carbon footprint of steam turbine manufacturing and operation.

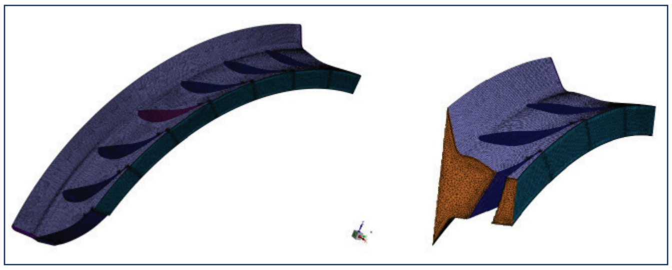
Customization, Modularization & Smart Workshops

Turbines today must meet a wide range of needs — from industrial cogeneration to nuclear power and geothermal applications. Research and development enable the creation of modular and customizable turbine platforms, allowing manufacturers to quickly adjust to different project scopes. In workshops, EyeTech barcode technology is now used for inventory control and component tracking. By scanning barcodes on raw materials and subassemblies, the system ensures real-time visibility of stock and streamlines production logistics, reducing human error and material waste

Artificial Training Programs for Human Capital Development

As turbine systems become more complex, workforce development is being reshaped by AI-driven training programs. These programs use augmented reality (AR), virtual reality (VR) and interactive simulation platforms to train teams in:

- Component identification and awareness
- Assembly techniques
- Site erection logistics and sequencing
- Commissioning procedures and safety compliance



These digital learning environments improve retention, lower field errors and prepare workers for both normal and emergency operations without needing costly physical mock-ups.

Collaborative Innovation Ecosystems

Research and development in steam turbine manufacturing is becoming more collaborative, involving OEMs, academic institutions, startups and government bodies. These ecosystems speed up breakthroughs in design, materials and digital systems, while also helping to standardize safety, interoperability and emissions regulations across the industry.

Conclusion

The steam turbine industry is undergoing a resurgence, fuelled by innovation in design, manufacturing and lifecycle management. Robotics-assisted blading, PLM-integrated CAD systems, smart workshops with barcode tracking, AI-powered training and predictive diagnostics are redefining industry standards. These advancements enhance efficiency, reliability and sustainability reinforcing the steam turbine's vital role in a flexible, future-ready energy landscape.

Triveni Turbines stands at the forefront of this transformation, exemplifying how an R&D-driven, homegrown approach can achieve global excellence in steam turbine manufacturing. ■

Author

S Narayana Prasad
Chief Executive Officer
Triveni Turbine Limited